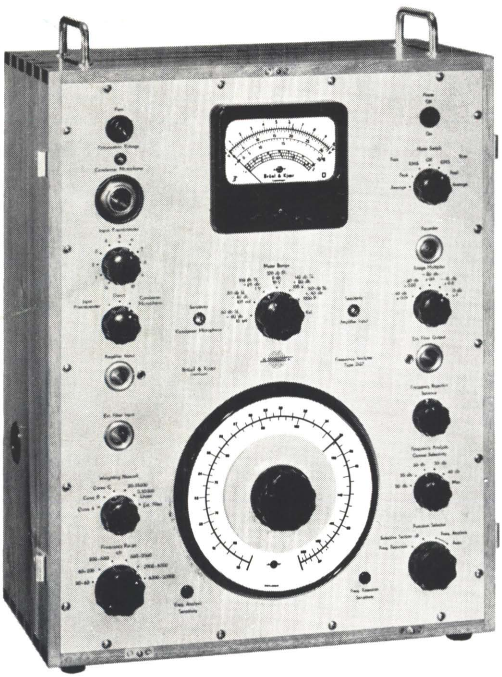
2107

INSTRUCTIONS AND APPLICATIONS

Frequency Analyzer Type 2107



An Audio Frequency Analyzer of the constant percentage bandwidth type. It has been designed especially as a Narrow Band Sound and Vibration Analyzer, but may be used for any kind of voltage and sound level measurements, frequency analysis, or distortion measurements within the range 20—20ooo c/s.

The instrument can be automatically tuned from an external motor and combined with the B & K Level Recorder for automatic recording of spectrograms. Built-in true RMS, arithmetic average, and peak rectifiers.

BRÜEL & KJÆR

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BB 2107

Frequency Analyzer

Type 2107

AUGUST 1962

Contents

Description

General.

Type 2107 is an AC operated audio frequency analyzer of the constant percentage bandwidth type. It has been designed especially as a narrow band sound and vibration analyzer, but may be used for any kind of frequency analysis and distortion measurement within the specified frequency range. A built-in mechanical device enables automatic tuning from an external

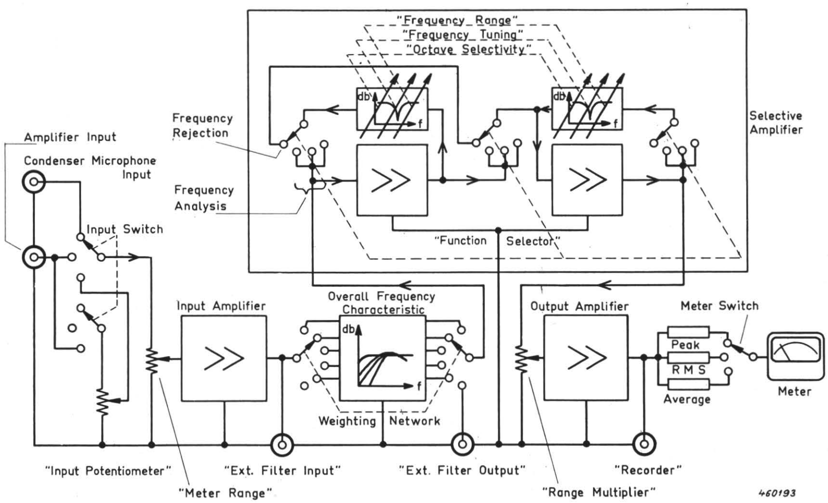


Fig. 1.1. Block diagram of the Frequency Analyzer.

motor, e.g. the motor in one of the B & K Level Recorders. When used together with a Level Recorder Type 2305 frequency amplitude diagrams can be recorded automatically on preprinted frequency calibrated recording paper. The analyzer can also be used as a linear amplifier and a vacuum-tube voltmeter. In addition it is supplied with the weighting networks for sound level measurements "A", "B" and "C" the characteristics of which are suggested by E.I.C. (Helsinki 1961) and a 7-poled input socket for connection of a B & K Condenser Microphone or Preamplifier as required.

The instrument is supplied with an output switch, by means of which the rectifier and meter circuit can be switched to measure either the peak, the arithmetic average or the true R.M.S. value of the input signal. To enable easy and accurate meter reading for both high and low frequency signals two different, standardized meter damping characteristics can be selected. A means is also provided for connection of external filters, for example the Band Pass Filter Set Type 1612 between the amplifier stages.

Technical Description.

The Frequency Analyzer Type 2107 consists of an input amplifier, a number of weighting networks, a selective amplifier section, and an output amplifier, see also block diagram Fig. 1.1.

Input Amplifier.

The input impedance measured at the "Amplifier Input" bushing is 2.22 MΩ which is the total resistance of the "Meter Range" attenuator. This attenuator consists of six selected resistors and four capacitors for frequency response compensation and is directly coupled to the grid of the first tube in the input amplifier.

The amplifier consists of two low-noise, low-microphonic twin triodes. The two halves of the first tube constitute a two-stage RC-coupled amplifier, and the two halves of the second tube are paralleled in a cathode-follower coupling. This paralleling, together with the great amount of negative feed-back ensure an output impedance at the "Ext. Filter Input" bushing of less than 10 Ω. The gain of the amplifier measured from the grid of the first tube (at the "Amplifier Input" bushing with "Meter Range" in position "10 mV") to the cathodes of the second tube (at the "Ext. Filter Input" bushing) is 40 db ± 2 db. The cathodes of the second tube are directly connected to the "Ext. Filter Input", and to ensure less than 0.1 % distortion of the output voltage this should not exceed 1 V r.m.s. sine-wave by a load of 500 Ω, or 10 V r.m.s. sine-wave by 5000 Ω.

Note: Since no coupling capacitor is present, a DC voltage of 60—100 volt can be measured across the "Ext. Filter Input" terminals. The max. DC load must not exceed 1 mA.

Overload Indicator: The output of the input amplifier is paralleled by an overload indicator. The indicator is so designed that it gives a visual indication when signal peak voltages exceed 4.5 V on the output of the input amplifier. The signal to be monitored is amplified in a triode connected pentode and fed to a gas tube, indicating overload by a red light. Refer also to item "Overload and Clipping" on page 10.

Weighting Networks.

The weighting network assembly is placed on a "drawer" on the center chassis of the apparatus. It is an L, C, R network with five different outputs corresponding to five different frequency characteristics: "2—40000 c/s, Linear", "20—40000 c/s", Curve A, Curve B and Curve C as shown in Fig. 1.2. The desired operating characteristic can be chosen by means of the switch marked "Weighting Network".

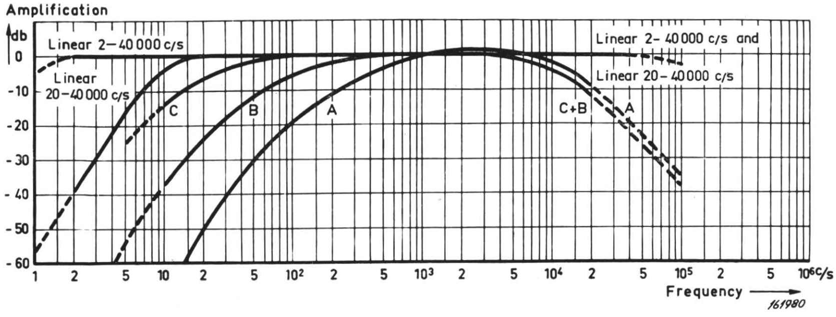


Fig. 1.2. Typical overall frequency characteristics of Type 2107.

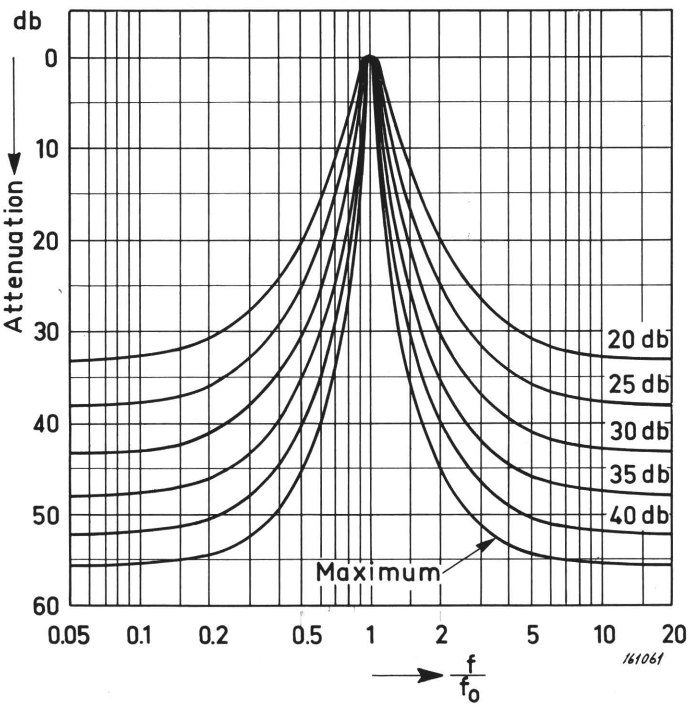


Fig. 1.3. Typical selectivity curves of the Analyzer. The number of db marked on the curves correspond to the setting of the "Frequency Analysis Octave Selectivity" knob.

Selective Amplifier Section.
The selective amplifier section is switched in by means of the "Function Selector" switch, see also the block diagram Fig. 1.1. When the switch is in one of the positions "Freq. Analysis" or "Auto" the instrument operates as a narrow band analyzer, which can be continuously swept through its entire frequency range 20—20000 c/s.
The frequency characteristic of the band-pass filter can be adjusted by the switch marked "Frequency Analysis Octave Selectivity". Typical response curves are shown in Fig. 1.3 where f_0 is the center frequency of the filter i.e. the frequency to which the Analyzer is tuned.
Around the "Frequency Analysis Octave Selectivity" knob the attenuation in db of a frequency one octave away from f_0 is marked. These selectivity values correspond to the following relative bandwidths of the selection filter:

Octave Selectivity in db	3 db Bandwidth in Percent
20	29
25	21
30	16
35	12
40	8.5
max. approx. 45	6

which by means of the graph shown in Fig. 1.4 can be transferred into parts of an octave.

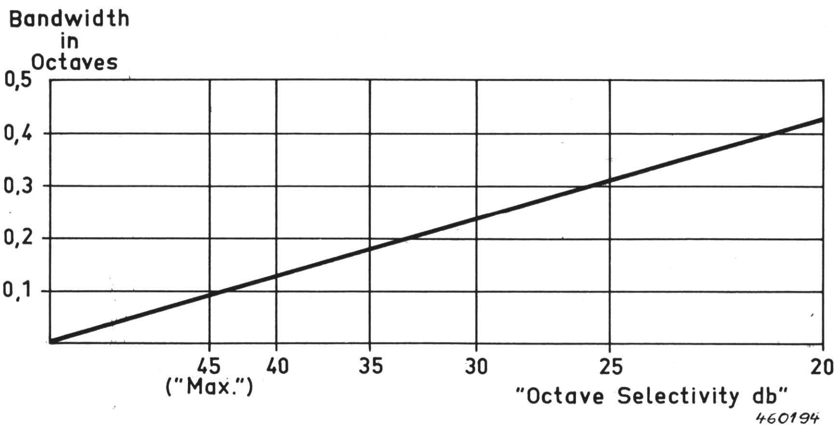


Fig. 1.4. Curve showing the correlation between the setting of the knob "Octave Selectivity db" and the filter bandwidth expressed in parts of octaves.

From the block diagram Fig. 1.1 it can be seen that the selective amplifier section actually consists of two series connected selective amplifiers. The band-pass characteristic of the Analyzer is obtained by a frequency rejective

negative feedback. To stabilize the amplifiers a certain amount of linear negative feedback is also introduced. Each amplifier contains a cascode coupled twin triode, a "bridge" tube and a cathode follower (one half of a twin triode).
The input signal to the first amplifier is fed to the "upper" half of the cascode and the linear negative feedback is introduced via the "bridge" tube to the cathode of the "lower" part of the cascode.
The selective feedback circuit is shown in Fig. 1.5. It consists of the "bridge" tube, a resistance-capacitance network of the "Wien-Bridge" type and a cathode follower. The output voltage from the first selective amplifier is taken from the plate of the "bridge" tube and fed to the second selective amplifier via the cathode follower. To obtain the required amount of feed-

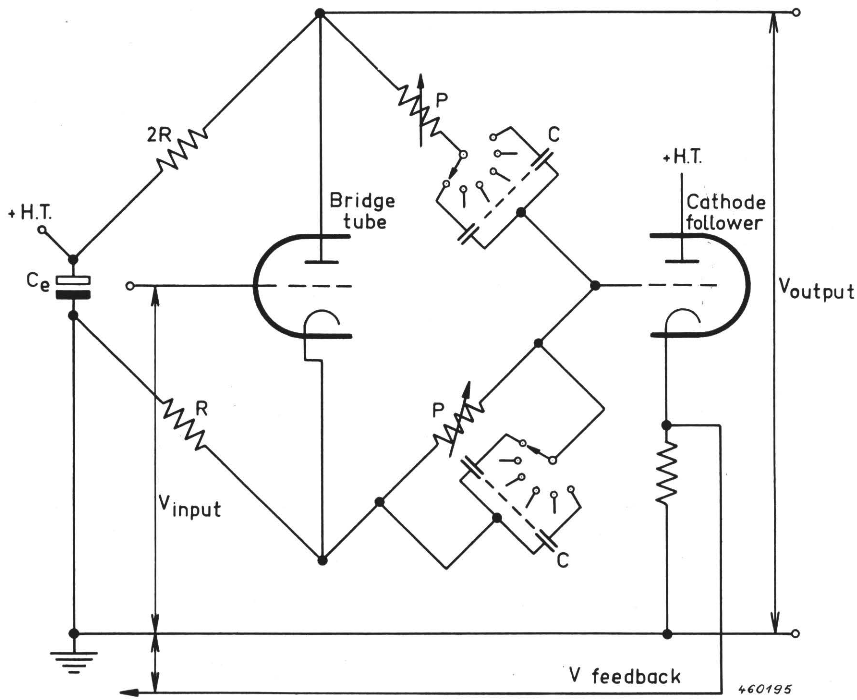


Fig. 1.5. Basic schematic diagram of the "Wien-Bridge" arrangement used in the selective feedback circuits of the Frequency Analyzer Type 2107.

back, the feedback voltage, $V_{feedback}$ developed in the Wien Bridge is fed to the grid of the "lower" part of the cascode. The extensive use of cathode followers in the selective amplifiers has been necessary to ensure correct impedance matching in the circuit.

of the cascode. The extensive use of cathode followers in the selective amplifiers has been necessary to ensure correct impedance matching in the circuit. The Wien Bridge consists of two pure resistors (R and 2R) and two arms containing a series RC network and a parallel RC network respectively. Although the DC supply for the "bridge" tube is inserted between the pure resistors, the bridge acts as a closed bridge with regard to AC, because of the 200 μF capacitor (C_e). At a certain frequency $f_o = \frac{1}{2\pi RC}$ the feedback voltage, ($V_{feedback}$), is zero, and consequently the gain of the selective amplifier section maximum. At other frequencies the feedback voltage, ($V_{feedback}$), is great. In this way the desired selective frequency characteristic of the Analyzer is obtained.

The second selective amplifier is identical to the one just described. If now the Wien Bridge was connected in series with the amplifier instead of in the feedback loop the resulting frequency characteristic of the Analyzer would be exactly inverted, i.e. it would reject the frequency to which it was tuned. This is a desirable feature when for instance distortion measure-

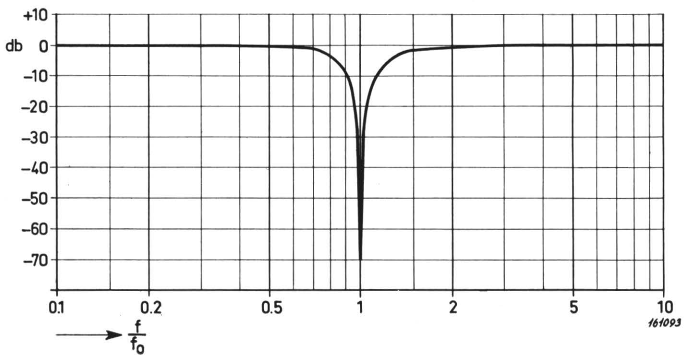


Fig. 1.6. Typical frequency rejection curve.

ments are undertaken. The "Function Selector" switch includes for this reason a position marked "Freq. Rejection. When the switch is in the "Freq. Rejection" position the final of the two series connected selective amplifiers is coupled as a linear amplifier with a 30 db gain. The first selective amplifier is switched so that the "Wien-Bridge" is connected in series with the amplifier, whereby the selective circuit acts as a rejection circuit, (see Fig. 1.1). A small amount of selective negative feedback is still maintained, which is necessary to ensure that the rejection curve is not more than 0.5 db down at the 2nd harmonic to the tuned-in frequency. To ensure perfect balance of the "Wien-Bridge" an additional potentiometer, "Frequency Rejection Balance", is introduced in one of the bridge arms. By

means of this potentiometer the bridge circuit can be brought in balance for any position of the frequency scale pointer. An attenuation of 70 db at the tuned-in frequency is obtainable, see Fig. 1.6.
To ensure correct gain of the Analyzer for all settings of the "Function Selector" switch two screwdriver operated gain adjustment potentiometers are provided. They adjust the gain of the selective amplifier section and are placed on the back of the instrument. One of them is marked "Freq. Rejection — Level Adjustment", and the other "Frequency Analysis — Level Adjustment".

Output Amplifier.
The signal from the selective amplifier section is fed to the output amplifier via the "Range Multiplier" switch.
The input impedance of the output amplifier is 1.46 MΩ as measured on the "Ext. Filter Output" bushing. The "Range Multiplier" attenuator consists of five selected resistors with a ratio of 10 db between two consecutive switch positions, and a trimmer capacitor for frequency characteristic compensation.
The output amplifier is a three-stage R-C coupled amplifier with negative feedback. The feedback can be adjusted by means of the two screwdriver-operated potentiometers, which are accessible through holes in the front plate of the instrument and marked "Sensitivity-Condenser Microphone" and "Sensitivity-Amplifier Input". The adjustment range of the potentiometers is approximately 6 db.
To ensure a low output impedance (less than 50 Ω) at the "Recorder" output bushing the output stage consists of a cathode follower. In addition capacitive feedback is accomplished through an adjustable bushing capacitor. This is done to reduce the input capacity of the output amplifier to a minimum, whereby the frequency response of the amplifier is less dependent on the setting of the "Range Multiplier" switch.*)
To the output cathode follower is also coupled the meter circuit. This circuit consists of diodes and resistors and gives the meter rectifier a characteristic which ensures true RMS rectification for any signal with a crest factor of five or less.**) A switch in the rectifier circuit also enables the arithmetic average and the peak (half the peak-to-peak) value of the input signal to be measured. The meter itself is a moving coil instrument with a maximum current consumption of o.2 mA. It satisfies the dynamic requirements for precision sound level meters as suggested by I.E.C. (Helsinki 1961).

Power Supply.
The power transformer is fused on the primary side. The secondary side consists of four separate windings, one for the plate voltage supply, one

*) For more detailed information see page 6-7, B & K Technical Review No. 3 July 1958.
**) For more detailed information on this circuit see B & K Technical Review, No. 3 July 1958.

for the voltage supply to the condenser microphone bushing, and two for the filament voltage supply. DC heating and special compensation arrangements have been employed on critical tubes circuits to decrease the hum level.
To facilitate the use of condenser microphones requiring different polarization voltages the polarization voltage supply for the microphone is made adjustable by means of a screwdriver-operated potentiometer located on the back of the instrument and marked "Polarization Voltage". The adjustable voltage range is 150 volts to 250 volts.

Reference Voltage.
The reference voltage is a 6.3 mV RMS zener-diode stabilized square-wave signal of the mains frequency.
When the Analyzer is switched for frequency analysis ("Function Selector" in position "Freq. Analysis" or "Auto") and turned to the frequency of the mains, only the fundamental of the square-wave reference signal is measured on the instrument meter. An adequate reference voltage correction is in this case automatically accomplished.

Overload and Clipping.
Care must be taken not to overdrive the input amplifier. By using the Analyzer in the nonselective condition overdriving of the amplifier sections can be observed on the indicating meter deflection i.e. within full deflection there is no overload, provided the signal crest factor is below 4.5. In the selective condition, overdriving of the output amplifier only can be observed on the indicating meter as signal components outside the pass-band of the filter or weighting network inserted are attenuated. To obtain an overload indication for the input amplifier a visual indicator is connected in parallel to the output of the input amplifier, as previously described. The indicator lights up when signal peak voltages on this point exceeds 4.5 volts (3.16 V r.m.s. sine-wave) i.e. 10 db higher than the 1 V r.m.s. sine-wave, as stated for o.1 % nonlinear distortion. The 4.5 volts peak voltage indication limits the measurements to signals with crest factor f_c lower than 4.5, which also is the highest crest factor allowable at full r.m.s. drive. The higher peaks in the signal have to contain a certain energy to be indicated. When for example measurements are made on noise signals with Gaussian distribution the indicator will only react for noise peaks, which are lower than approximately 2.5 times the r.m.s. value, i.e. f_c lower than 2.5.
To be able to check on how far the input amplifier is driven in making selective measurements, the "Function Selector" of the Analyzer should first be set to position "Selective Section off" and "Range Multiplier" on "0 db, x 1". The r.m.s. average or peak drive of the amplifier can then be read on the indicating meter. Full deflection corresponds to 1 volt on the output of

the input amplifier. From the above can be seen, that in selective measurements, when the input amplifier is driven to maximum, the sensitivity of the Analyzer can only be increased by "Range Multiplier".

Mechanical Parts.

The continuously frequency scan of the Analyzer can be done manually as well as remotely. For remote operation the scanning is attained via a worm gear with ratio 25 : 1 from an external drive, for example one of the B & K Level Recorders. A magnetic clutch arrangement permits the set and release of the automatic drive. The clutch is DC operated by a 600 Ω coil with an operating voltage of 20 volts. By means of a set of toothed wheels the scanning mechanism is connected to the "Frequency Range" switch switching this automatically once per completed turn of the scale pointer, i.e. each time one of the six frequency ranges are scanned.

Identification of Control Knobs, Terminals etc.

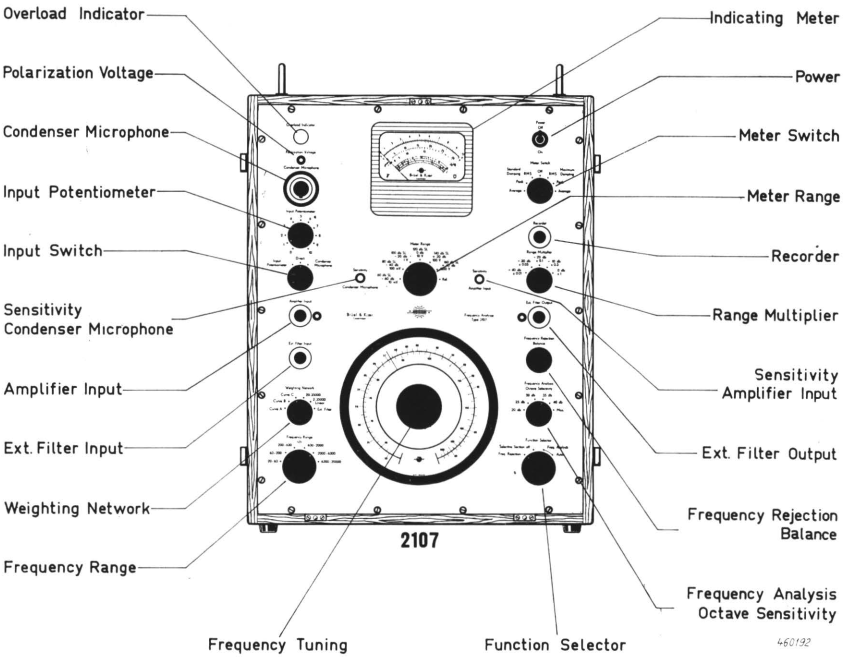


Fig. 2.1. Frequency Analyzer Type 2107 with control knob identification. identification.

Front Plate.

Overload Indicator: Indicates for peak voltages higher than 4,5 V, i.e. 10 db above 1 V r.m.s., on the output of the input amplifier.

"Polarization Voltage": For measuring of the microphone polarization voltage. A DC voltmeter with an internal resistance of at least 20ooo ohm/volt should be connected between this terminal and ground (chassis).

"Condenser Microphone": Input terminal for the B & K Condenser Microphones (Cathode Followers) and Preamplifiers.

"Input Potentiometer": For continuous attenuation of input signal.

"Input Switch": Selection of one of the three input facilities
"Input Potentiometer", to be used for relative measurements.
"Direct". The signal is applied direct from the "Amplifier Input" to the attenuator "Meter Range".
"Condenser Microphone".

"Sensitivity, Condenser Microphone": Screwdriver operated potentiometer, for adjustment of sensitivity, when input "Condenser Microphone" is used.

"Amplifier Input": The signal is applied to the attenuator "Meter Range" either direct or via the "Input Potentiometer", depends on position of "Input Switch".

"External Filter Input": Intended for connection of external filter input, parallels the output of the input amplifier.
Note: A DC voltage of approximately 75 volts is present. Do not drain more than 1 mA d.c.

"Weighting Network": "Curve A", "B" or "C" is switched in.
Connected in cascade with the selective amplifier section when "Function Selector" is set to position "Freq. Rejection", "Freq. Analysis" or "Auto".
"Linear, 20—40ooo" c/s, a network is switched in cutting of below 20 c/s with a maximum slope of 18 db/octave.
"Linear, 2—40ooo" c/s the Analyzer is switched as linear amplifier, when the "Function Selector" is set to position "Selective Section off".
"Ext. Filter". External filter connected to "External Filter Input" and "External Filter Output" is switched in.

"Frequency Range": For selection of the six frequency ranges.

"Frequency Tuning": For setting of frequency within the ranges of "Frequency Range" for analysis and rejection.

"Power": For switching off and on the power for the apparatus.

"Meter Switch": For selection of the three different meter indicating properties

"Average"
"Peak" (half peak-to-peak)
"R.M.S."

The three positions ("Fast") to the left gives the smallest damping of the indicating meter deflection. The positions ("Slow") to the right give the highest damping. In the middle position "Off", the meter circuit is disconnected.

"Meter Range": Step attenuator, 20 db, for attenuation of input signal.

"Recorder": Output terminal.

"Range Multiplier": Step attenuator, 10 db. Inserted between selective amplifier section and output amplifier.

"Sensitivity, Amplifier Input": Screwdriver operated potentiometer for adjustment of sensitivity when terminal "Amplifier Input" is used.

"External Filter Output": Intended for connection of the output of an external filter. Is switched in circuit with the input of the selective amplifier section when "Weighting Network" is set to "Ext. Filter" position.

"Frequency Rejection Balance": To obtain maximum rejection of a signal selected on the Frequency Tuning scale, with the "Function Selector" set in the "Freq. Rejection" position.

"Frequency Analysis Octave Selectivity": To select six different degrees of selectivity (bandwith) of the band-pass filter when "Function Selector" is set to the "Analysis" or "Auto" position.

"Function Selector": "Freq. Rejection". Any signal of a distinct frequency selected on the Frequency Tuning scale, can be rejected. Maximum attenuation is attained by adjusting the "Frequency Rejection Balance".

"Selective Section off". The selective amplifier section is switched out of circuit, i.e. the frequency response of the Analyzer is solely determined by the position of the "Weighting Network" switch.

"Freq. Analysis". The Analyzer is set for analysis of signals the frequency of which are selected on the Frequency Tuning scale. Six different bandwidths can be chosen by the "Frequency Analysis, Octave Selectivity" switch.

"Auto". Same data as obtained in the "Frequency Analysis" position but an electromagnetic clutch is operated, clutching in the remotely controlable and mechanic frequency scanning arrangement.

Rear of Instrument. (Refer Fig. 2.2)

Mains Voltage Selector and Fuse Holder: The fuse should be of 1.5 amp. (medium lag).

Adjustment Potentiometers: Screwdriver operated potentiometers accessible through the perforation of the rear plate. The potentiometers identified by "For factory adjustment only" should not be adjusted unless a factory adjustment of the Analyzer is carried out. For adjustment of the remaining potentiometers, refer to part Operation.

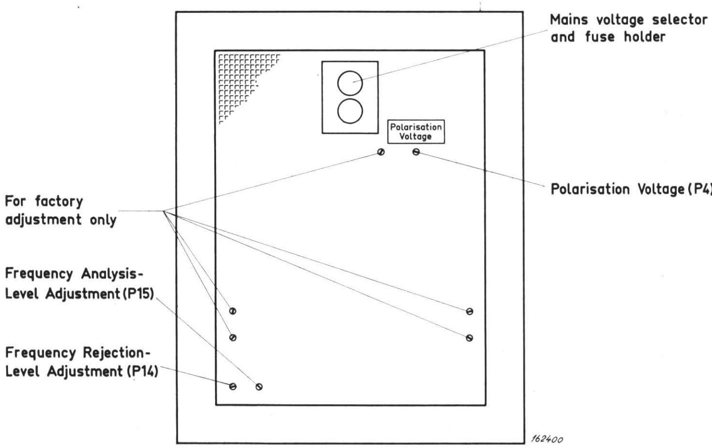


Fig. 2.2. Rear view of Frequency Analyzer Type 2107.

Operation

Sensitivity Adjustments

1. Check that the instrument is set to the correct power voltage. Switch on and allow a few minutes to warm-up.
2. Set the knobs listed in the following positions:—

"Input Switch"	to	"Direct"
"Weighting Network"	to	"2—40ooo Linear"
"Frequency Range"	to	"20—63"
"Function Selector"	to	"Selective Section off"
"Frequency Analysis Octave Selectivity"	to	"20 db"
"Range Multiplier"	to	"× 1 (0 db)"
"Meter Switch"	to	"Fast, RMS"
"Meter Range"	to	"Ref.'

3. Adjust the "Sensitivity Amplifier Input" until a meter deflection to the red mark on the meter scale is obtained.
4. Set Input Switch to "Condenser Microphone".
5. Adjust the "Sensitivity Condenser Microphone" until a deflection to the red mark on the meter scale is obtained.
6. Set

"Input Switch"	to	"Direct"
"Function Selector"	to	"Freq. Analysis"

   and turn the frequency scale to the mains frequency.
7. If a meter deflection is not obtained to the red mark on the scale adjust the potentiometer marked "Frequency Analysis — Level Adjustment" at the rear of the instrument (Fig. 2.2) until this is achieved.
8. Set

"Frequency Range"	to	"200—630"
"Function Selector"	to	"Freq. Rejection"

9. If a meter deflection is again not immediately obtained to the red mark on the scale, adjust the potentiometer marked "Freq. Rejection — Level Adjustment" on the back of the instrument until accomplished.

Voltage Measurements.

To use the Analyzer as a normal VTVM apply the following procedure:

1. Check the sensitivity of the Analyzer. See "Sensitivity Adjustment" item 1 through 3.

2. Adjust the "Meter Range" and "Range Multiplier" switches until a suitable meter deflection is obtained (between 3 and 10 on upper volt scale) when the signal to be analyzed is fed to the "Amplifier Input" of the Analyzer. (The "Range Multiplier" switch should, when possible, be in either of the two positions "× 1 (0 db)" or "× o.3 (— 10 db)").
3. Read off the meter. Full scale sensitivity is equal to the "Meter Range" indication (V or mV) multiplied by the factor indicated by the position of the "Range Multiplier" switch.

Frequency Analysis.

Selective measurements can be carried out in the frequency range from 20 c/s to 20ooo c/s. To adjust the Analyzer for measurement apply the following procedure:

1. Check the sensitivity adjustment. See "Sensitivity Adjustment" page 11.
2. Set the "Input Switch" to "Condenser Microphone" if the "Condenser Microphone" input is used. To "Direct" if the "Amplifier Input" is used for absolute measurements, and to "Input Potentiometer" if the "Amplifier Input" is used for relative measurements.
3. Set the "Weighting Network" switch to "Linear, 20—40ooo" if normal frequency analyses is wanted.
   to "Curve A", "Curve B" or "Curve C" if a frequency weighted analysis is desired, see also Fig. 1.2.
4. Set the "Frequency Range" switch to the frequency range of interest.
5. Set the "Function Selector" to "Selective Section off".
6. Set the "Frequency Analysis Octave Selectivity" to the desired selectivity.
7. Set "Range Multiplier" to "× 1 (0 db)".
8. If not otherwise required set "Meter Switch" to "Fast, RMS".
9. Adjust the "Meter Range" and "Range Multiplier" switches until a suitable meter deflection is obtained (between 3 and 10 on upper volt scale) when the signal to be analyzed is fed to the input of the Analyzer. (The "Range Multiplier" switch should when possible be in either of the two positions "× 1 (0 db)" or "× o.3 (—10 db)").
10. Switch the "Function Selector" switch to "Frequency Analysis".
11. Turn the frequency scale pointer to the frequency to be examined and read meter. If the meter reading is below 3 on the upper volt scale turn the "Range Multiplier" switch (*not the* "Meter Range" switch) counter-clockwise until a suitable meter deflection is obtained.
12. Turn the frequency scale pointer to measure other frequencies of interest and switch "Frequency Range" if required.

Distortion Measurements.

The measurement of distortion can be carried out by measuring the harmonics individually. To do this, apply the procedure outlined under "Frequency Analysis" above. If it is desired to directly measure the distortion factor, apply the following procedure:

1. Check the sensitivity adjustment. See "Sensitivity Adjustment" page 11.
2. Set the "Input Switch" to "Input Potentiometer", and apply the signal to be measured to the "Amplifier Input".
3. Turn "Input Potentiometer" fully clockwise.
4. Set the "Weighting Network" switch to "20—40ooo".
5. Set the "Frequency Range" two ranges away from the frequency range which contains the fundamental frequency of the input signal.
6. Set the "Function Selector" to "Freq. Rejection".
7. Set the ""Range Multiplier to "× 1 (0 db)".
8. Set the "Meter Switch" to "Fast, RMS".
9. Adjust the "Meter Range" and "Range Multiplier" switches until a suitable meter deflection is obtained (between 3 and 10 on upper volt scale) when the signal to be analyzed is fed to the input of the Analyzer. (The "Range Multiplier" switch should, when possible, be in either of the two positions "× 1 (0 db)" or "× o.3 (—10 db)").
10. Turn the "Range Multiplier" one step counterclockwise and the "Input Potentiometer" counterclockwise until full scale deflection is obtained on the meter.
11. Set "Frequency Range" to the range containing the fundamental frequency of the input signal, and turn the frequency dial of the Analyzer to this frequency (minimum deflection on the meter). By means of the "Frequency Rejection Balance", fine adjustment to minimum meter deflection should be carried out.
    The reading on the meter is now the distortion factor with "10" on the "upper" volt scale corresponding to 100 %, "9" to 90 %, "8" to 80 % etc. If a deflection below "3" on this volt scale is obtained, turn the Range Multiplier" one position counterclockwise. The distortion factor is then read in percent on the "lower" volt scale with "30" corresponding to 30 %, "20 to 20 % etc. If a meter reading smaller than "10" on the lower volt scale is obtained, turn the "Range Multiplier" further counterclockwise by one position. The upper volt scale "10" now corresponds to 10 %, "9" to 9 % etc.

Sound Level Measurements.
To carry out accurate sound level measurements the sensitivity of the microphone must be known. When the Analyzer is used with a microphone connected to the "Amplifier Input", the meter reading is in volts and the sound level must be calculated on the basis of the microphone sensitivity. When the Analyzer is used with the Brüel & Kjær Condenser Microphones Type 4131 or 4132, however, the meter reading can be read directly in db SL (decibel sound level). To do so apply the following procedure:—

1. Check that the polarization voltage is correct. The polarization voltage can be measured between the bushing marked "Polarization Voltage" and ground and is adjusted by means of a screwdriver-operated potentiometer

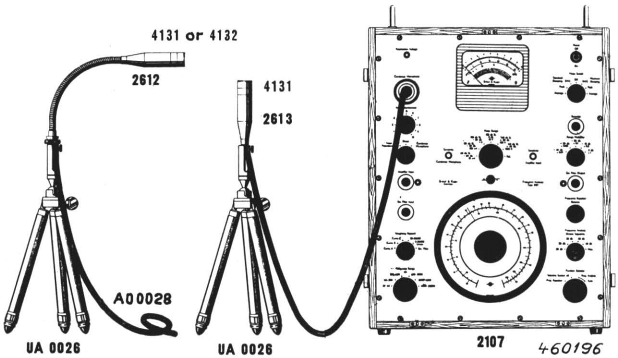


Fig. 3.1. Connection of a B & K Condenser Microphone to the Frequency Analyzer for sound level measurements.

on the rear of the instrument. *Note:* The current consumption of the voltmeter used to measure the polarization voltage should be max. 50 μA.

2. Connect the Condenser Microphone as shown in Fig. 3.1.

3. Set

Set	Input Switch	to	Condenser Microphone
	Function Selector	to	Selective Section "off"
	Weighting Network	to	20—40000
	Range Multiplier	to	0 db, × 1
	Meter Range	to	Ref.
	Meter Switch	to	Fast, RMS

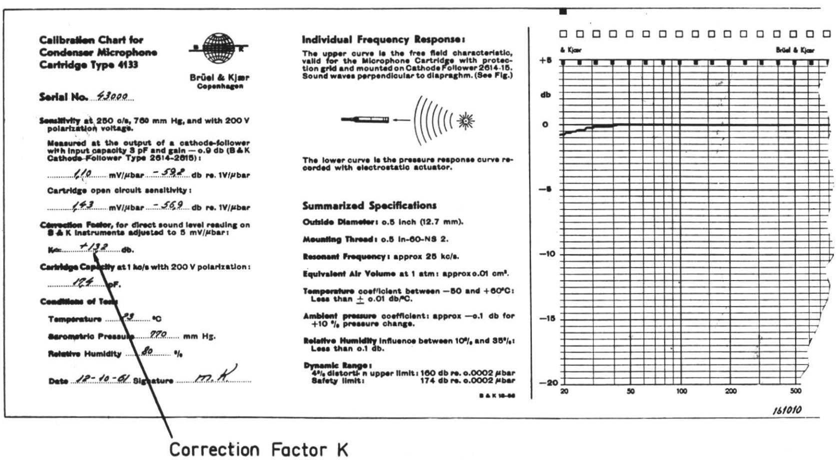


Fig. 3.2. Typical microphone calibration chart with indication of the correction factor "K".

4. From the Microphone calibration chart the correction factor "K", (Fig. 3.2), is found.

5. Adjust the screwdriver-operated potentiometer marked "Sensitivity-Condenser Microphone" until the meter pointer deflects to the red mark on the scale + "K" db.

6. Expose the Microphone to the sound to be measured and thereafter adjust the "Meter Range" and "Range Multiplier" switches until a suitable meter deflection is obtained (between 3 and 10 on upper volt scale) The "Range Multiplier" switch should when possible be in either of the two positions "× 1 (0 db)" or "× o.3 (— 10 db)".

7. The sound pressure level*) measured is now equal to "Meter Range" indication (db SL) + "Range Multiplier" indication (db) + meter reading (db).

8. If a measurement of the sound level**) is desired, the "Weighting Network" switch is set to position Curve C, Curve B or Curve A. Specify clearly, together with the measured result, which of the networks has been used.

The following table may be taken as a guide with respect to the use of the different weighting networks. (It is often, however, convenient to use all three networks to determine which part of the sound spectrum is the most predominant one).

Loudness	Weighting Network inserted
0— 60 db SL	Curve A
60—130 db SL	Curve B
130 db SL	Curve C

*) Sound pressure level is the level of the sound pressure when measured on an instrument with linear frequency characteristic (20—20ooo c/s).
**) Sound level is the level of the sound pressure when measured on an instrument using one of the internationally standardized weighting curves (Curve A, Curve B, Curve C)

Automatic Recording of Voltage Analysis.

If the Analyzer is connected to a Level Recorder Type 2305 the analysis of complex signals can be recorded automatically on preprinted recording paper. The measurement will appear as a calibrated frequency/amplitude diagram of the measured signal. However, the paper drive on the Level Recorder

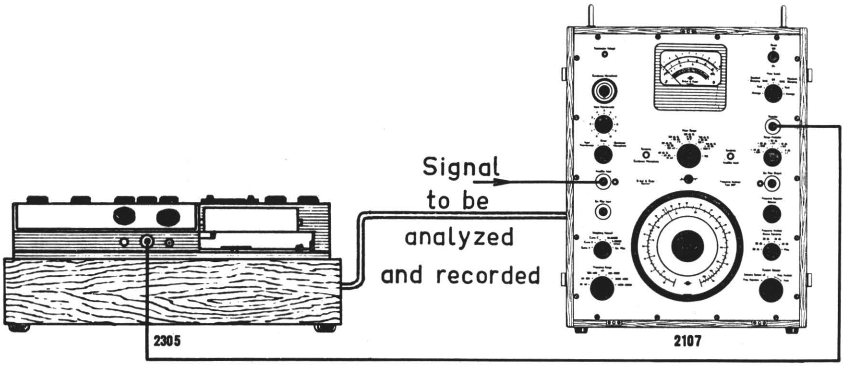


Fig. 3.3. Measuring arrangement used for the automatic recording of voltages.

must be synchronized with the frequency sweep of the Analyzer. To realize this condition connect the instruments as shown in Fig. 3.3 and proceed as follows:—

1. Adjust the Analyzer as outlined under "Sensitivity Adjustment" item 1 through 3.
2. Make sure that the Level Recorder is adjusted for the correct mains voltage and switch the "Power" switch of the Recorder to "On". (In the following the use of a 50 db Range Potentiometer is assumed. If other Range Potentiometers are employed, see "Range Potentiometer Correction", page 18).

   Then set:—

   "Potentiometer Range db" to "50"
   "Rectifier Response" to "RMS"*)
   "Lower Limiting Frequency" to "20"
   "Writing Speed" 100 mm/sec. (large figures)
   200 mm/sec. (small figures)
   "Paper Drive" to "Stop" and "Forward"
   "Single Chart-Continuous Recording" pushbutton in its released (upper) position
   Allow a few minutes warm-up time
   "Motor" to "On"
   "Input Attenuator" to "10"

---

*) Or "Average" or "Peak", depending upon which type of signal detection is desired.

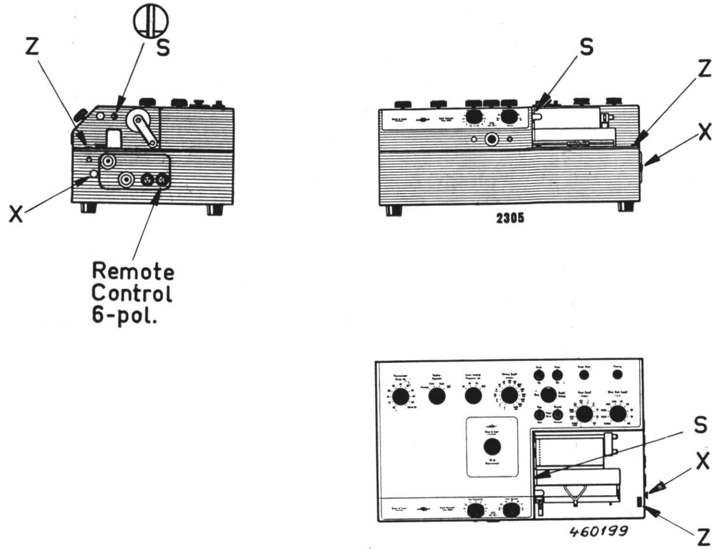


Fig. 3.4. Drawing of the Level Recorder with indication of the synchronizing lever "x", the screw "s" and the finger wheel "z".

By means of the "Input Potentiometer" the writing stylus is adjusted to full deflection —4 db. (For the 50 db Range Potentiometer 50 — 4 = 46 db).

3. Synchronize the Level Recorder and the Analyzer:

Insert the frequency calibrated paper QP 1130 in the Level Recorder, see also the instruction manual for Type 2305.
Pull the lever, "X", to its outer position, see Fig. 10.
Turn the screw, "S", shown in Fig. 3.4 by means of a screwdriver, until the marking cut in the screw is in its down position.
Set the "Paper Speed" knob to the desired position, small figures. The knob is operated by pulling and turning.
The toggle switch "Paper Drive" is set to "Start", whereby the paper starts moving. If not, press the pushbutton "Single Chart — Continuous Recording" and release it again immediately.
Move the recording paper by means of the finger wheel, "z", in Fig. 3.4 until the writing stylus points at the "20" c/s line or the "63" c/s line depending upon at which frequency it is desired to start the analysis.
Set the frequency dial pointer on the Analyzer to "20" or "63", and the "Frequency Range" switch to the desired position.*)

*) It is possible to analyze and record the input signal in any frequency interval between 20 c/s and 20ooo c/s. However, normally the analysis is started at 20, 200, 2ooo c/s or at 63, 630, 6300 c/s. The adjustment of the "Frequency Range" switch should thus be made accordingly.

4. Adjust the "Meter Range" and "Range Multiplier" switches until a suitable deflection is obtained on the recording paper, preferably between the 40 and 50 db lines. (The "Range Multiplier" switch should when possible be in either of the two positions × 1 (0 db) or × o.3 (—10 db)).
Set the "Frequency Analysis Octave Selectivity" switch to the desired selectivity.
Set "Function Selector" to "Auto".

Start the recording by pressing and releasing the pushbutton "Single Chart — Continuous Recording" on the Level Recorder. The paper will now automatically move approximately one frequency decade, and then stop. If recording over more than one decade is required, the pushbutton "Single Chart — Continuous Recording" should be pressed and released again.
It is also possible to record the analysis continuously. In this case the "Single Chart — Continuous Recording" pushbutton should be pressed and turned clockwise, whereby it will be locked in the down position. To stop the recording it must be turned counterclockwise and released again.

Range Potentiometer Correction.
If other than the 50 db Range Potentiometer is used on the Level Recorder, the following modifications to the operation procedure for "Automatic Recording of Voltage Analyses", item 2, page 16, are necessary:

Range Potentiometer used	Recommended position of "Potentiometer Range db"	Recommended position of "Writing Speed"	Position of "Input Attenuator"
10	10	63 (125)	"30"
25	25	160 (315)	"30"
75	80	400 (800)	"0"

The Level Recorder "Input Potentiometer" shall in all cases, except when a 75 db Range Potentiometer is employed, be adjusted for full stylus deflection on the recording paper minus 4 db, i.e.:—
For the 10 db Range Potentiometer: Stylus deflection 10 — 4 = 6 db
For the 25 db Range Potentiometer: Stylus deflection 25 — 4 = 21 db
If the Recorder is supplied with a *75 db Range Potentiometer,* however, the "Input Potentiometer" should be adjusted for full stylus deflection on the paper *minus 19 db* (= 56 db).
Note: Only signals with crest factors around 1 will be correctly recorded with a 75 db Range Potentiometer and full stylus deflection.

Recording Evaluation.

To determine the input signal level to the Analyzer from the recording the following summation should be carried out:

Number of db indicated by the stylus deflection on the recording paper
+ number of db (*not* db SL) indicated by the position of the "Meter Range" switch
+ number of db (negative numbers) indicated by the position of the "Range Multiplier" switch
— number of db on the Range Potentiometer (except in case a 75 db Range Potentiometer is used)
= signal level in db re 10 V.

Note: If a 75 db Range Potentiometer is employed on the Recorder, *the number of db to be subtracted is 60* instead of 75, see also Example 3.

Example 1.

Recorder utilising a 50 db Range Potentiometer.
Deflection of the writing stylus at one particular frequency: 36 db.
"Meter Range" switch position: "20 db".
"Range Multiplier" switch position: "—10 db".
The signal level is then:
$36 + 20 - 10 - 50 = -4$ db re. 10 V i.e. 6.3 Volt.

Example 2.

Recorder utilising a 25 db Range Potentiometer.
Deflection of the writing stylus: 19 db.
"Meter Range" switch position: "0 db".
"Range Multiplier" switch position: "0 db".
The signal level is in this case:
$19 + 0 + 0 - 25 = -6$ db re. 10 V i.e. 5 Volt.

Example 3.

Recorder utilising a 75 db Range Potentiometer.
Deflection of the writing stylus: 60 db.
"Meter Range" switch position: "0 db".
"Range Multiplier" switch position: "0 db",
whereby the signal level is:
$60 + 0 + 0 - 60 = 0$ db re. 10 V i.e. 10 Volt.

Automatic Recording of Sound Spectra.

Sound spectra can be measured and recorded automatically by means of the arrangement shown in Fig. 3.5. The Analyzer is in the case supplied with a B & K Condenser Microphone and connected both mechanically and electrically to a Level Recorder Type 2305. To carry out the recording proceed as follows.

1. Adjust the Analyzer and Level Recorder as outlined under "Automatic Recording of Voltage Analyses", page 21, item 1 through 3.
2. Check that the microphone polarization voltage is correct. The polarization voltage can be measured between the bushing marked "Polarization

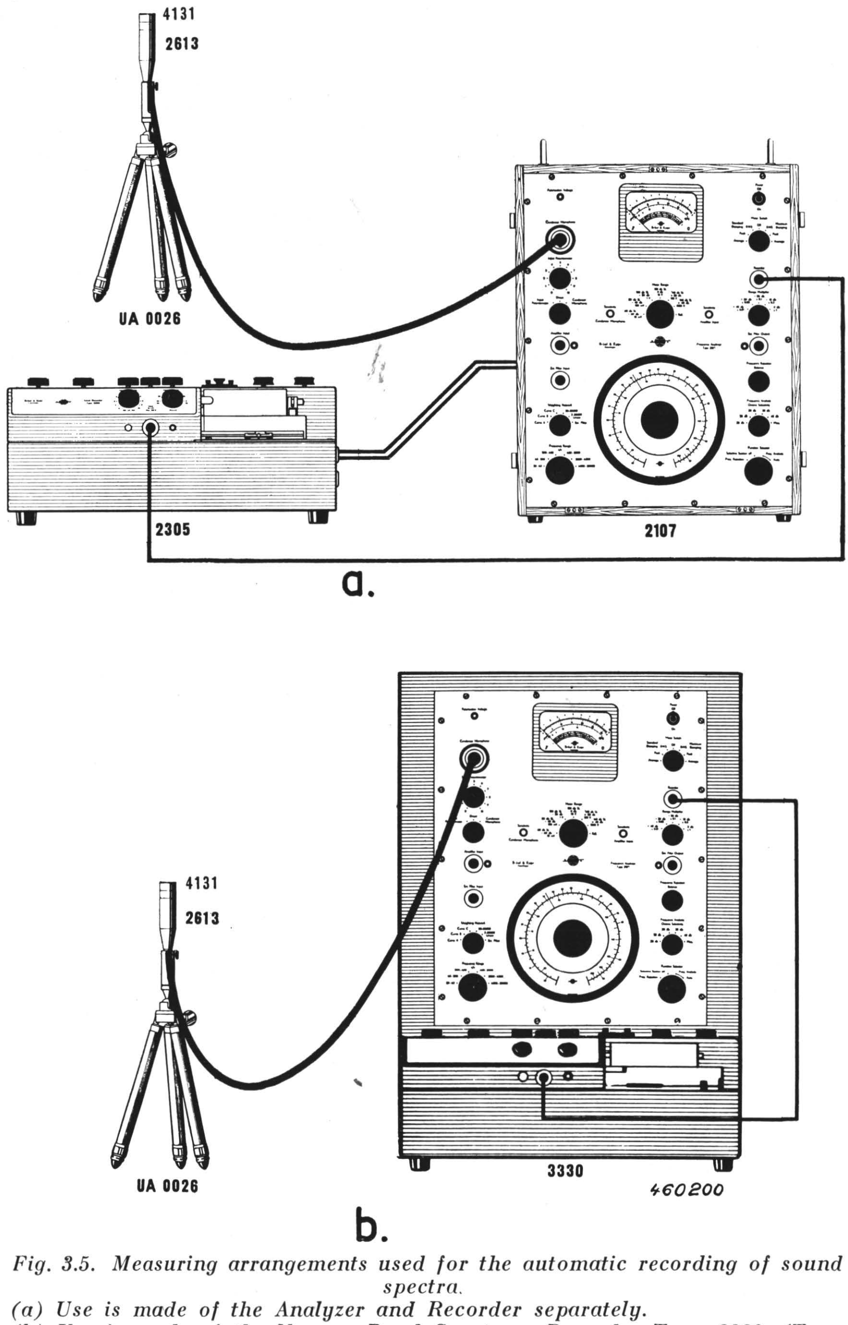
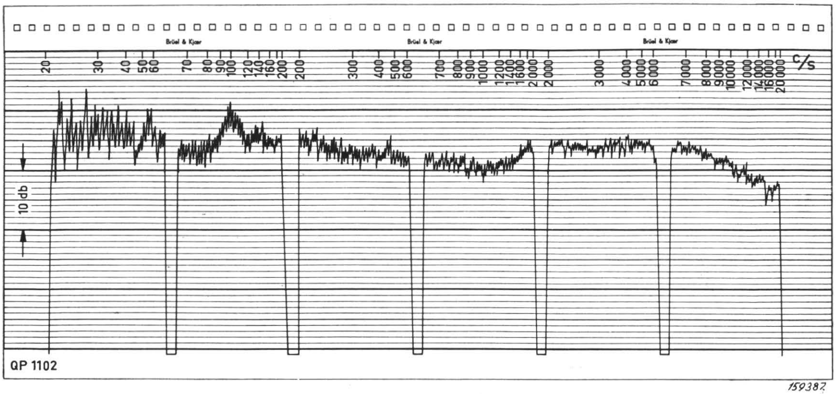
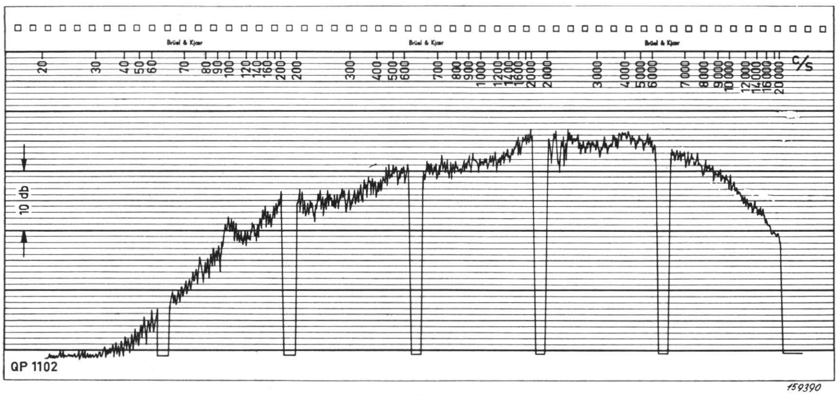


Fig. 3.5. Measuring arrangements used for the automatic recording of sound spectra.
(a) Use is made of the Analyzer and Recorder separately.
(b) Use is made of the Narrow Band Spectrum Recorder Type 3330. (Type 2107 and 2305 built together in a metal rack).



(a)



(b)

Fig. 3.6. Recordings obtained from selective measurement of noise with the "Weighting Network" switch in two different positions.
(a) "Weighting Network" switch in position "20—40ooo c/s".
(b) "Weighting Network" switch in position "Curve A".

Voltage" on the front panel of the Analyzer and ground. Possible corrections are carried out by means of a screwdriver operated potentiometer on the rear of the instrument.

Note: The current consumption of the Voltmeter used to measure the polarization voltage should be max. 50 μA.

3. Set the Analyzer "Input Switch" to "Condenser Microphone".
4. From the Microphone calibration chart the correction factor "K", Fig. 3.2, is found.
5. Adjust the screwdriver operated potentiometer marked "Sensitivity — Condenser Microphone" on the Analyzer front panel until the meter pointer deflects to the red mark on the scale + "K" db.

6. Adjust the "Meter Range" and "Range Multiplier" switches until a suitable deflection is obtained on the recording paper, preferably between the 40 and 50 db lines. (The "Range Multiplier" switch should when possible be in either of the two position × 1 (0 db) or × o.3 (— 10 db)).

   Set the "Frequency Analysis Octave Selectivity" switch to the desired selectivity.

   Set "Function Selector" to "Auto".

Start the recording by pressing and releasing the pushbutton "Single Chart — Continuous Recording" on the Level Recorder. The paper will now automatically move approximately one frequency decade and then stop. If recording over more than one decade is required, the pushbutton "Single Chart — Continuous Recording" should be pressed and released again. It is possible to record the analysis continuously. In this case the "Single Chart — Continuous Recording" pushbutton should be pressed and turned clockwise, whereby it will be locked in the down position. To stop the recording it must be turned counterclockwise and released again.

If it is desired to record a frequency weighted spectrogram this can be done by setting the "Weighting Network" switch to one of the positions "Curve A", "Curve B" or "Curve C" instead of "2—40ooo Linear", refer Fig. 3.6.

Evaluation of the Sound Spectrogram.

The evaluation of the recorded sound spectrogram can be carried out in a manner similar to the procedure described in connection with "Automatic Recording of Voltage Analyses".

When a 50 db Range Potentiometer is used on the Level Recorder the sound pressure level at some particular frequency is:—

Writing stylus deflection in db + db S. L. indicated by the "Meter Range" switch position + db on the "Range Multiplier" switch — 30 = S. P. L. in db re. 2×10^{-4} μbar.

If a 10 db Range Potentiometer is used the sound pressure level will be:—

Writing stylus deflection in db + db S. L. on the "Meter Range" switch + db on the "Range Multiplier" switch + 10 = S. P. L. in db re. 2×10^{-4} μbar.

If a 25 db Range Potentiometer is used:—

Writing stylus deflection in db + db S. L. on the "Meter Range" switch + db on the "Range Multiplier" switch — 5 = S. P. L. in db re. 2×10^{-4} μbar.

If a 75 db Range Potentiometer is used:—

Writing stylus deflection in db + db S. L. on the "Meter Range" switch + db on the "Range Multiplier" switch — 40 = S. P. L. in db re. 2×10^{-4} μbar.

Example:

Recorder supplied with a 50 db Range Potentiometer.

Deflection of the writing stylus at one particular frequency: 36 db.

"Meter Range" switch position: "100 db S. L.".

"Range Multiplier" switch position: "—10 db".
S. P. L. = 36 + 100 — 10 — 30 = 96 db re. 2×10^{4} μbar.

Use of Reference Sound Sources for Calibration.

The calibration methods previously described in this manual for sound level measurement and recording have required no "extra" apparatus. They have all been based on the use of the built-in reference voltage of the Analyzer and conversion factors for the Microphone.

Simpler and more direct methods of calibration consist of producing a sound of known sound pressure level at the Microphone diaphragm. The Analyser and Recorder should then be adjusted so that the known sound pressure level corresponds to a certain deflection on the Analyzer meter—or of the Recorder writing stylus—for a specific setting of the control knobs. However, any change in control knob setting during measurement must be taken into account when the measured result is evaluated.

Brüel & Kjær produce two different sound sources for calibration and checking purposes, a battery-operated Pistonphone Type 4220 and a mechanical Noise Source Type 4240. Both units are designed for "mounting" on the Microphone during calibration, see Fig. 3.7, and each instrument is individually calibrated. The R.M.S. sound pressure level produced by the Pistonphone is around 124 db re. 2×10^{-4} μbar, the actual value being stated on the instrument calibration chart and referred to an ambient atmospheric pressure of 1 Bar. The accuracy of the value stated on the chart is $\pm$ o.2 db, and the measuring frequency is around 250 c/s. The Pistonphone is a highly accurate

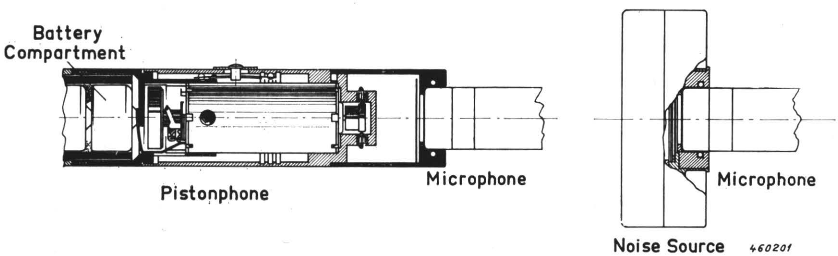


Fig. 3.7. Sketch showing how the Pistonphone Type 4220 and the Noise Source Type 4240 are placed on the Microphone during calibration checks.

instrument and may be used for the absolute calibration of microphones as well as for calibration of complete measuring arrangements.

The Noise Source is intended mainly for calibration checks on measuring set-ups. It is an entirely mechanical device, and requires no batteries for operation. The R.M.S. sound pressure level produced by the Source is around 110 db re. 2×10^{-4} μbar, the actual value being inscribed on the instrument. As the name implies the sound constitutes a continuous spectrum and the accuracy of a check by means of the Noise Source will be around $\pm$ 1.5 db.

For further information regarding the Pistonphone and the Noise Source the reader is referred to the corresponding instruction manuals and data sheets.

Applications

Distortion Measurements.

One of the main applications of the Frequency Analyzer Type 2107 is the analysis of non-sinusoidal voltages. Because of the relatively narrow band of the Analyzer (approx. 6 %) up to around ten harmonics can be measured with a reasonably high degree of accuracy.

If it is desired to find the distortion factor of the voltage being measured the signal can either be analyzed and the different harmonics be added geometrically, or the distortion factor can be measured directly. Fig. 4.1 shows the distortion of a 50 c/s signal in the form of a frequency spectrum. The rather great distortion is developed in an overdriven special amplifier, and the different harmonics are measured separately by means of Type 2107. The result of the geometrical addition is given in the figure, (7.15 %).

A direct measurement of the distortion factor is carried out by switching the Analyzer for "Frequency Rejection", rejecting the fundamental, and measuring the "rest" with the instrument meter switch in the R.M.S. position. This type

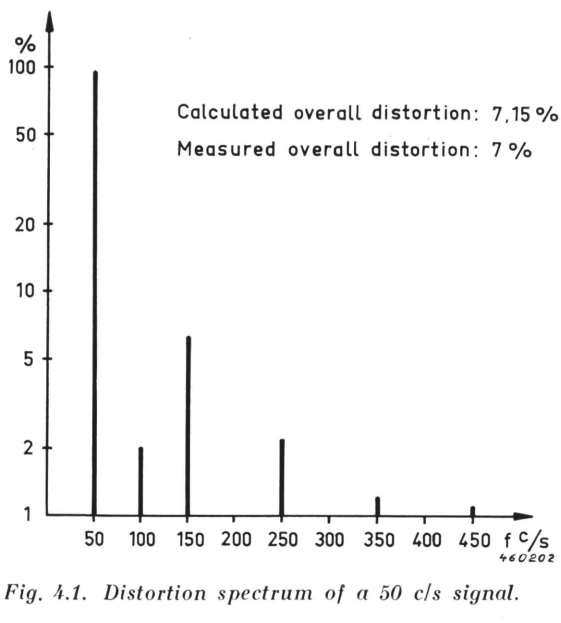


Fig. 4.1. Distortion spectrum of a 50 c/s signal.

of measurement was also carried out on the above mentioned 50 c/s signal, and the result can be seen on the figure (7 %). By this method distortion factors down to around 0.5 % can be measured.

If very low distortion has to be measured, use should be made of the Frequency and Distortion Measuring Bridge Type 1607. The Bridge can reject any distinct frequency signal by more than 80 db in the range 20—20000 c/s. When connecting the Bridge in series with the Frequency Analyzer in such a manner that the fundamental in the measured signal is rejected before reaching the Frequency Analyzer, distortions lower than 0.01 % can be measured. By the Analyzer the various harmonics are measured, and afterwards they have to be added geometrically.

Measurements of this type were carried out on a Beat Frequency Oscillator Type 1017, and the result obtained tabulated below.

Fundamental	2nd harmonic	3rd harmonic
1000 c/s	2000 c/s	3000 c/s
100	0.1	0.12

Distortion Factor: $d \cong \frac{\sqrt{0.1^2 + 0.12^2}}{100} = 0{,}156\ \%$

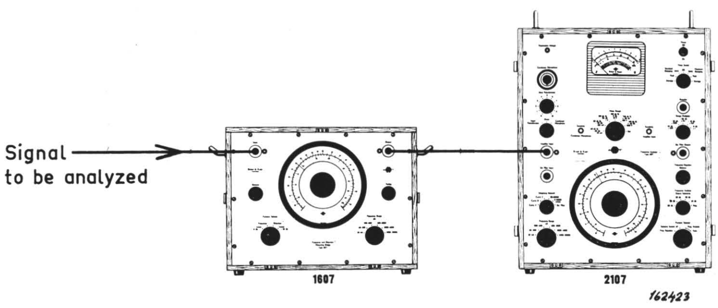


Fig. 4.2. Connection of the Distortion Measuring Bridge Type 1607 to the Frequency Analyzer Type 2107 for the measurement of distortion lower than 0.01 %.

The Frequency Analyzer Type 2107 as a Bridge Indicator.

When bridge measurements are carried out in the audio frequency range it is a great advantage to have a selective instrument in the bridge network because the disturbing noise level is proportional to the square-root of the instrument bandwidth. The only requirement that the bridge must satisfy is that one diagonal point can be readily grounded as shown in Fig. 4.3. This requires the bridge to be supplied from an oscillator via a screened transformer e.g. TU 0005, the signal generator generally being grounded at one terminal.

The balancing transformer TU 0005 contains two precision resistors and serves as one half of the bridge circuit. A total output impedance from the transformer of 600 Ω is obtained, and the balance between the two transformer "arms" is better than 0.1 %. The voltage transmission loss of the transformer when loaded by 600 Ω is approximately 16 db and the distortion less than 0.5 % for a transformer input voltage 12 V approx.

Due to the selectivity and great sensitivity of the Frequency Analyzer it is well-suited as an indicating instrument in a bridge circuit. Furthermore, the decibel scale on the instrument meter will prove of use when it is desired to measure the quality of different components placed in the bridge.

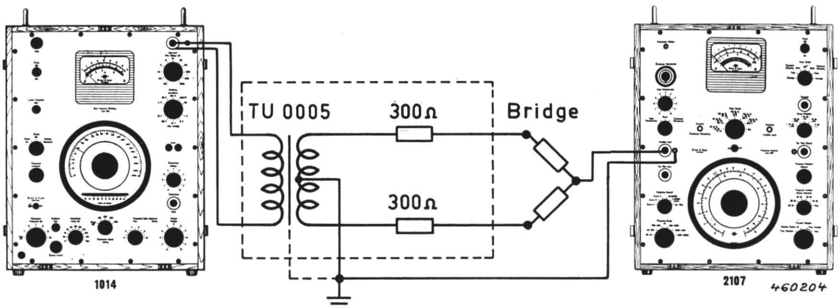
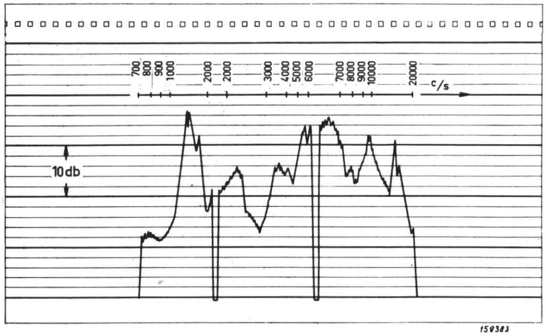


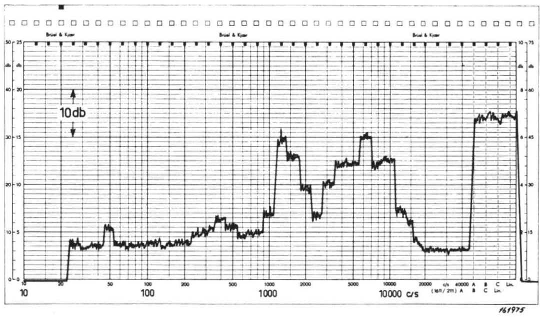
Fig. 4.3. The Analyzer used as bridge indicator.

Automatic Narrow Band Frequency Analysis.

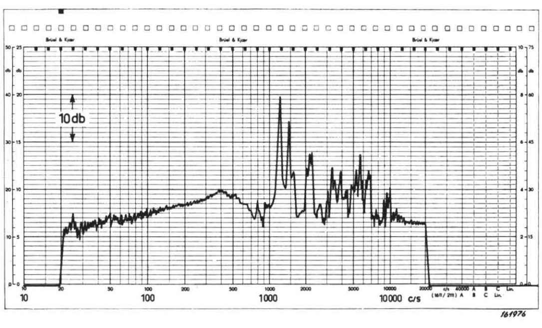
A great advantage of the Analyzer Type 2107 is that it can be automatically frequency tuned from an external motor drive. By driving the tuning mechanism from the motor in the Level Recorder Type 2305 the frequency spectrum of the Analyzer input signal can be recorded automatically on pre-printed, frequency calibrated recording paper. As the "Frequency Range" switch of the Type 2107 is automatically operated so that it switches from one range to the next for each full turn of the frequency scale pointer, complete automatic recording over the entire frequency range of the Analyzer is possible. However, frequently only some parts of the spectrum are of special interest, and the instrument is ideal for thorough investigation of these specific portions, its minimum bandwidth being around 6 % of the tuned-in frequency.



(a)



(b)



(c)

Fig. 4.4. Analysis of vacuum-tube microphonics.

(a) The tube is acoustically excited by means of random noise. Analysis performed by means of Type 2107 (maximum selectivity).

(b) Same excitation as in (a), but the output is analyzed by means of the Spectrometer Type 2112 (⅓ octave bandwidths).

(c) The tube is excited by means of pure tones.

Another important feature of Type 2107 is that it is continuously tunable whereby a relatively true picture of all the "valleys" are obtained when a continuous frequency spectrum is being analyzed. This is best illustrated by means of an example:

The upper curve (a) shown in Fig. 4.4 was obtained from measurements of the microphonic effect of a mounted vacuum tube. The tube was acoustically excited by means of random noise and the output voltage analyzed by means of Type 2107.

As comparison the middle curve (b) shows the result of a similar analysis, this time performed by means of a ⅓ octave continuous band analyzer (Type 2112). The bottom curve (c) shows the result obtained from measurements on the tube when is was excited by means of pure tones. Note the distinct difference between curve (a) and (b).

The recording shown in Fig. 4.4b was measured by means of a Spectrometer Type 2112 and a Level Recorder. However, instead of using Type 2112 the same result can be obtained by connecting the ⅓ Octave Filter Set Type 1612 to the external filter terminals of the Analyzer Type 2107 and operating the Analyzer as a linear amplifier with the "Weighting Network" switch in position "External Filter". The instrument is then equivalent to a Spectrometer Type 2112, see also Fig. 4.5.

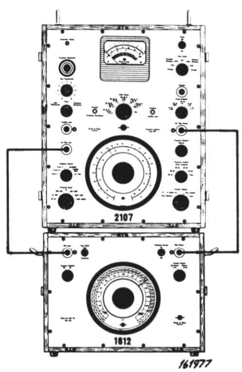


Fig. 4.5. Connection of the Band Pass Filter Set Type 1612 to the Frequency Analyzer Type 2107, thus transforming the Analyzer into a Spectrometer similar to Type 2112.

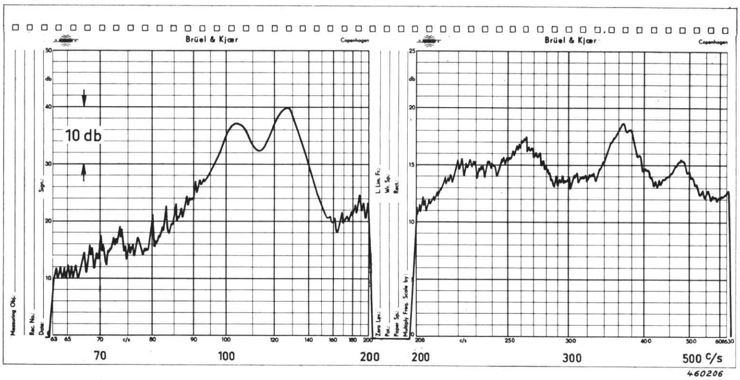
Noise Measurements and Recording.

The Frequency Analyzer Type 2107 can, when supplied with one of the B & K Condenser Microphones be used to analyze acoustic noise, or it can be used as a sound level meter. If the arrangement is connected to a Level Recorder

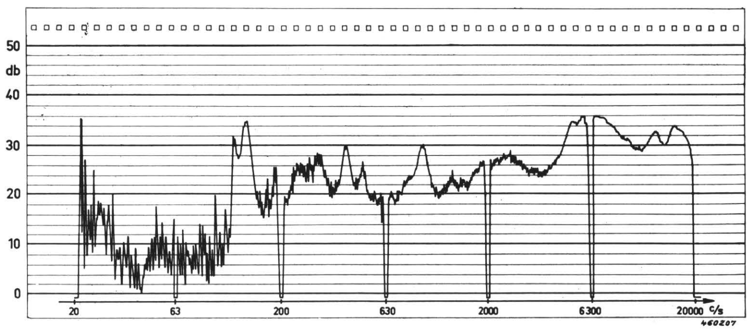
Type 2305, sound spectra or time records can be recorded automatically on preprinted recording paper.

Fig. 4.6a shows the recording of the most interesting parts of the sound spectrum produced by a small electric motor. The recording was made on preprinted frequency calibrated paper, and a "compressed view" of the complete spectrum from 20 c/s to 20ooo c/s is shown in Fig. 4.6b. From the "compressed view" the important parts of the spectrum were determined, and these "parts" were then recorded on precalibrated paper, Fig. 4.6a.

Fig. 4.7 shows a time record of the noise in an office where a number of people are working together. The main noise is produced by typewriters.



(a)



(b)

Fig. 4.6. Recordings of the sound spectrum produced by an electric motor.
(a) Recordings of the most "interesting" parts of the spectrum.
(b) Compressed view of the complete spectrum.

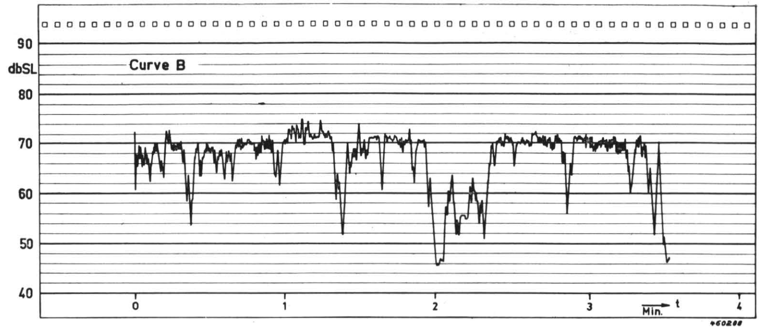


Fig. 4.7. Time record of office noise.

Vibration Measurements.

By using one of the B & K Accelerometers and Preamplifiers or Cathode Followers together with the Frequency Analyzer Type 2107 and a Level Recorder Type 2305 mechanical vibrations in machinery, buildings, ships, aircraft etc. can be analyzed and recorded.

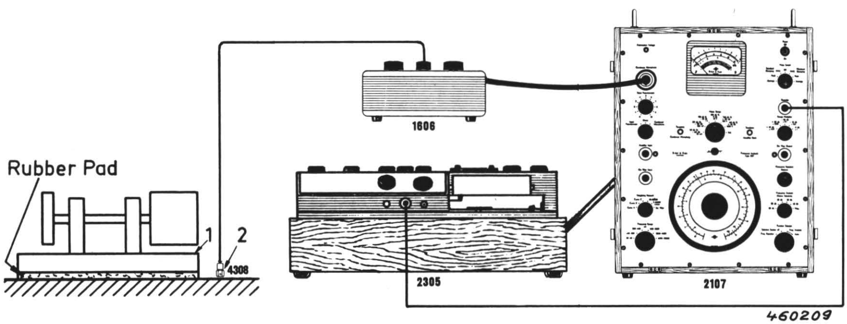


Fig. 4.8. Typical vibration measuring arrangement.

The use of a Preamplifier or Cathode Follower as a connecting link between the Accelerometer and the Frequency Analyzer is necessary to enable low frequency vibrations to be measured correctly. (The relatively low input impedance of the Analyzer would otherwise influence the low frequency cut-off of the Accelerometer to a too great extent).

Fig. 4.8 shows a typical measuring arrangement used for vibration measurements on a motor installation in a factory. Use is made here of the Preamplifier Type 1606 which also contains a small shaker table for calibration of the measuring arrangement. It also contains integrating networks which enable not only the acceleration but also the velocity and displacement of the vibrations to be measured by means of an accelerometer.

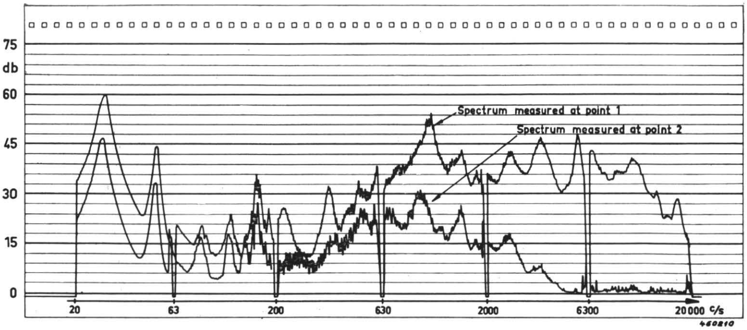


Fig. 4.9. Curves showing the vibration insulation of a relatively complicated machine mounted on the floor by means of rubber pads.

In Fig. 4.9 the vibration spectrum of the machine as measured on its foundation is shown together with the spectrum measured on the floor. The difference between the two curves gives the vibration insulation value in decibels. The peaks on the curves are caused by resonances occuring in different parts of the relatively complicated machinery.

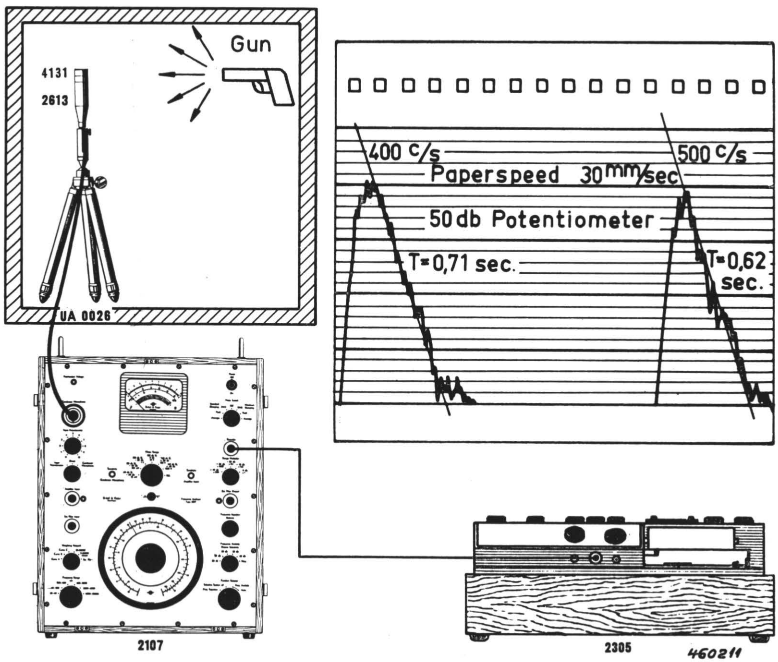


Fig. 4.10. Measurement of reverberation time using a gun as sound source. Typical curves measured by means of this method are also shown.

Measurement of Reverberation Time.

One of the most important factors determining the acoustic properties of a room is its reverberation time. This time may be measured in different ways and two of the methods which can be employed will be discussed in the following. Common for both methods is the use of a sound source, a microphone, an amplifier, and a level recorder.

Using a selective amplifier such as the Frequency Analyzer Type 2107 the sound produced by the sound source can have the character of white noise. By tuning the Analyzer to the frequency at which it is desired to measure, only a narrow band signal, centered at this frequency, will be present at the Analyzer output.

A typical measuring arrangement of this type is shown in Fig. 4.10, where a small gun is used as sound source. When the gun is fired, the sound level at the microphone will first rapidly increase, and then decrease again accord-

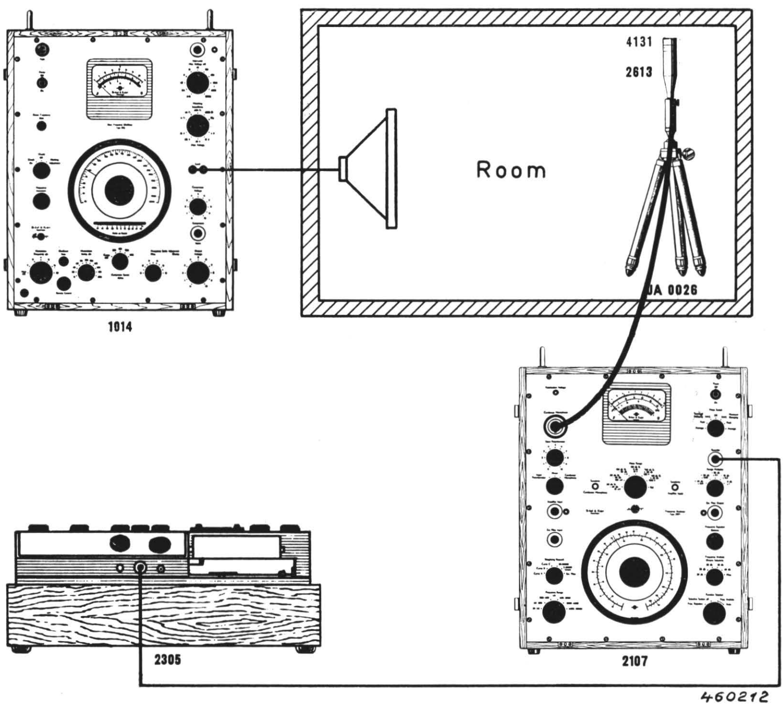


Fig. 4.11. Measurement of reverberation time using a B.F.O. and loudspeakers as sound source.

ing to the reverberant properties of the room. By recording the output from the Analyzer as shown in Fig. 4.10 the reverberation decay curve is found, and from this curve the reverberation time, as defined by W. C. Sabine, is easily determined with the aid of the Reverberation Curve Protractor SC 2361. This method is convenient when only a limited number of reverberation curves are to be measured.

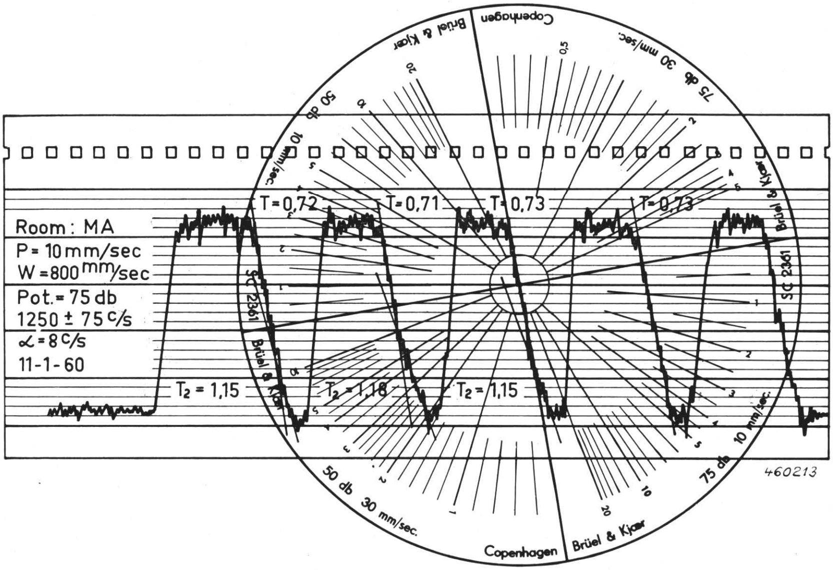


Fig. 4.12. Typical reverberation curves recorded by means of the arrangement shown in Fig. 4.11. Evaluation of the reverberation time with the aid of the Protractor is also indicated.

However, when a great number of curves should be recorded, the use of a gun as sound source is unsatisfactory as it requires one shot per curve. It is then advantageous to employ the second method of measurement, where the sound source consists of a Beat Frequency Oscillator Type 1014 and one or more loudspeaker units, see Fig. 4.11.

Also in this case, though it might not be strictly necessary, it is recommended to employ the technique of selective measurements. A much larger level range can then be employed for the recording of reverberation curves, thereby facilitating a more accurate evaluation of the measured results.

To record the reverberation decay curve the sound source is shut off by pressing the button marked "Oscillator Stop" on the B.F.O., where the oscillator should be frequency modulated to obtain reverberation curves with only small fluctuations, see Fig. 4.12.

Sound Insulation Measurements.

Fig. 4.13 shows a typical measuring arrangement which can be used for the measurement of airborne sound insulation of wallpartitions and floors in buildings. The insulation between room 1 and 2 is determined by producing a relatively high sound level in room 1, using a Random Noise Generator Type 1402, a power amplifier and loudspeaker as sound source, and recording the sound spectrum first in room 2 and then in room 1, see Fig. 4.14. From the difference between the two curves the sound insulation is found, after correction has been made for the absorption of the receiver room.

The reason for first measuring the sound pressure level in room 2 is to

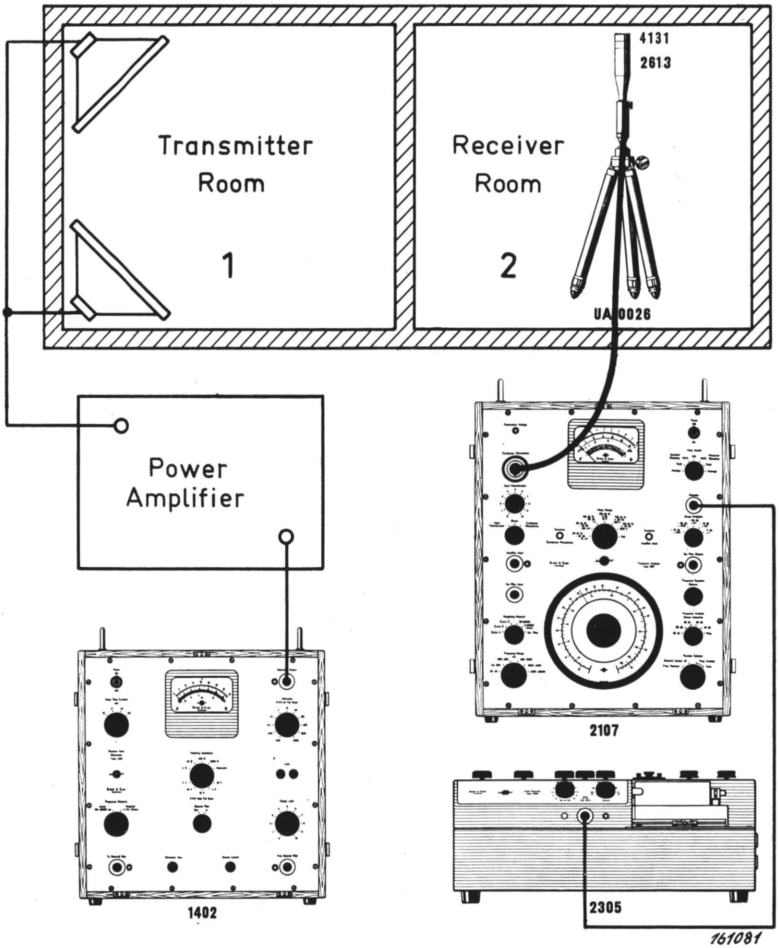


Fig. 4.13. Measurement of airborne sound insulation.

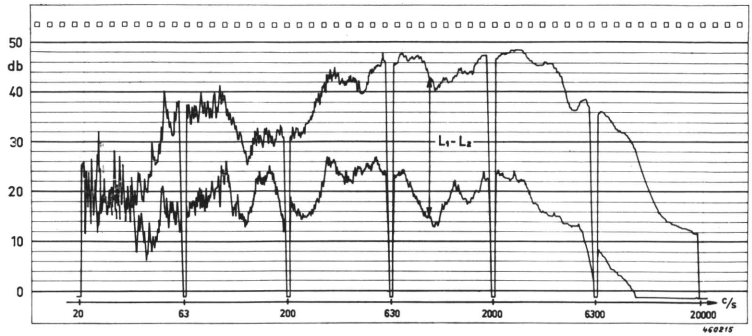


Fig. 4.14. Recordings obtained from measurements carried out as shown in Fig. 4.13.

ensure that the sound produced in room 1 is loud enough to be detected in room 2.

The correction factor taking the absorption of the receiver room into account is 10 $\log_{10} \frac{A_r}{S}$ where A_r is the total absorption of the receiver room and S is the area of the wall or floor partition being tested. The sound insulation, or sound transmission loss, is then:—

$$T.L. = L_1 - L_2 - 10 \log_{10} \frac{A_r}{S}$$

$L_1 - L_2$ is the difference in db between the sound pressure level in room 1 and room 2 at any particular frequency at which it is desired to determine the transmission loss and can be read directly from the recording Fig. 4.14.

The above mentioned random noise generator and loudspeaker may be replaced by some sort of noise producing motors or machinery, which produce a sufficiently wide frequency band for the measurements in question. An especially simple and inexpensive measurement can be made of the sound insulation of a mechanical workshop, where the machinery within the workshop itself may constitute the sound source.

Absorption Measurements on Sound Insulating Materials.

The sound absorbing properties of different materials may be evaluated from reverberation measurements, or a direct measurement of the absorption coefficient can be carried out with the aid of the Standing Wave Apparatus Type 4002. As shown in Fig. 4.15 the Beat Frequency Oscillator Type 1014 feeds a loudspeaker, mounted at the end of a measuring tube. The frequency of the B.F.O. is kept constant during each measurement, and the measuring tube is terminated by the acoustical sample to be tested. Because of the reflection of the incident sound wave from the sample under test a standing wave pattern is set up in the tube.

The ratio between maxima and minima of the standing wave is determined exclusively by the absorption of the terminating material. The ratio can be

found by measuring a maximum and the successive minimum value of the sound pressure with a probe microphone. The microphone of Type 4002 is shielded in a housing which is mounted on wheels and runs along a track in such a manner that the probe may be positioned anywhere along the central axis of the tube.
To avoid the influence of noise and harmonic distortion, which might occur when the absorption coefficient of the sample to be tested is small, the measurement should be carried out selectively. The output voltage from the microphone is therefore fed to the input of the Frequency Analyzer Type 2107, which is tuned to the frequency of the Oscillator. The indicating meter of the Analyzer is equipped with a set of scales from which the absorption coefficient can be read directly, see also the meter scale on top of Fig. 4.15.

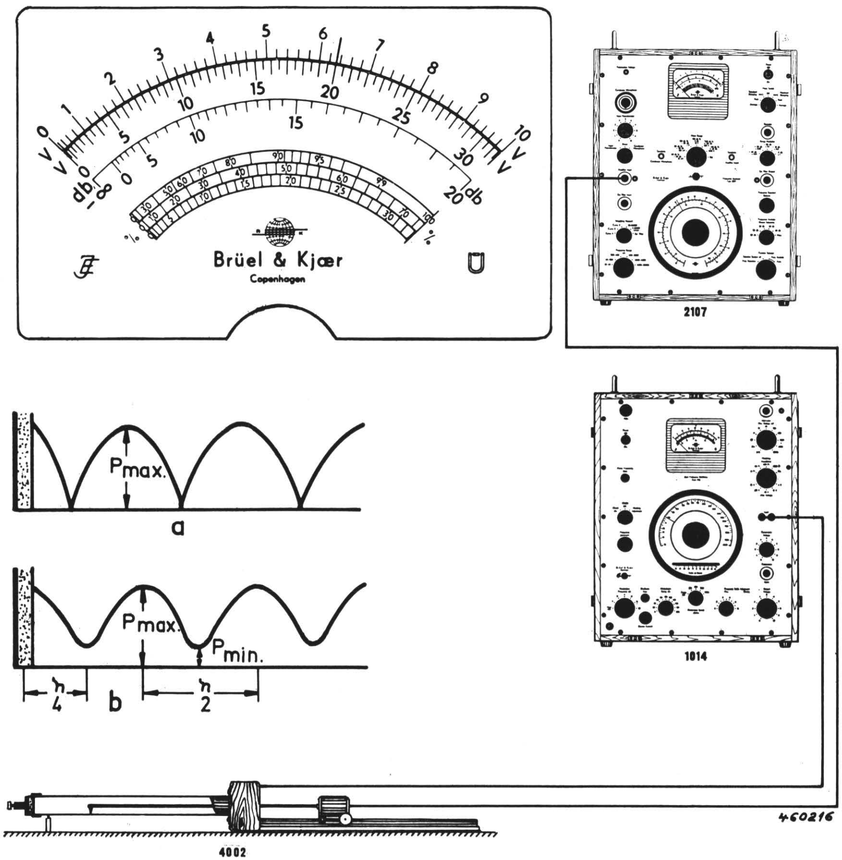


Fig. 4.15. Measurement of the acoustic absorption coefficient.

Appendix

ERRORS DUE TO PHASE DISTORTION

Phase Distortion. Common amplifiers will always give more or less phase distortion at their low and high frequency limits. The distortion will normally become perceptible about a decade higher than the lower frequency limit and about a decade lower than the higher frequency limit. Vide Fig. A.1a.

The phase distortion of an amplifier has no influence on the majority of its applications as far as the signal is a pure sine-wave or pure sine waves *with no phase relation,* i.e. when the distinct frequencies do not comprise the harmonics of a signal. If the output signal from the amplifier is rectified and measured by an indicating meter measuring the r.m.s., average and half peak-to-peak value of the signal, the phase distortion of the amplifier still has no influence on the measured result if the input signal has the character described above.

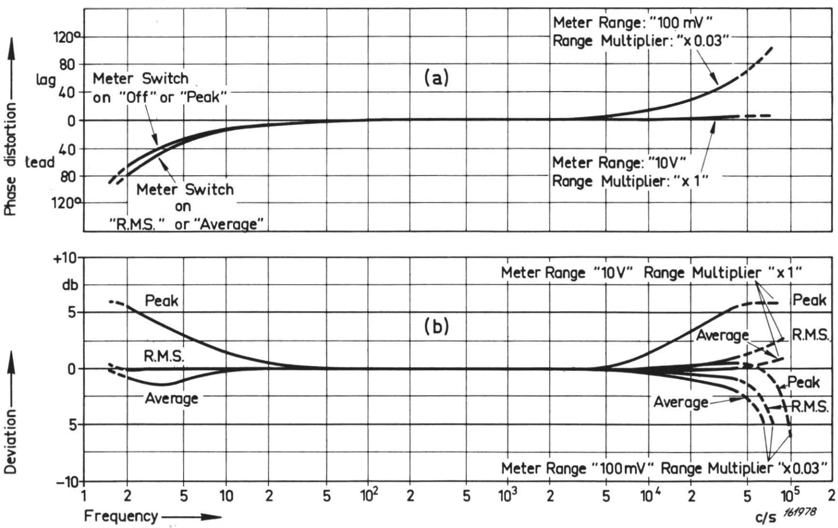


Fig. A.1. Typical deviation in r.m.s., average and peak reading from a symmetrical square-wave signal with the Frequency Analyzer phase response as comparison.
(a) Phase response of Frequency Analyzer.
(b) Deviation in reading.

On the other hand, if the signal applied to the amplifier consists of a complex signal with a number of harmonics, (as is the case for instance with a square-wave and a triangular signal) the shape of the signal will be distorted when treated in an amplifier which has phase distortion. When the amplitude vs. frequency characteristics of the amplifier is practically straight in the range of the signal frequency components, the number of harmonics and their original amplitude relationships are unchanged in the phase distorted signal. If this signal is measured on the amplifier output by the r.m.s., average and peak-to-peak measuring indicating meter, the following will be noted:—

R.M.S. Measuring: This is by far the most important for the majority of investigations. When using this characteristic of the rectifier circuit, the phase relation between the different components of the signal has no influence. *Therefore, by measuring a phase distorted signal by an r.m.s. measuring meter the same value will be read as for the undistorted signal.*

Average Measuring: In this case the arithmetic average value of the signal deviates from the value of the original signal when phase distorted.

Peak Measuring: When utilizing the half peak-to-peak property of the indicating meter a considerable deviation from the original value is measured, when the signal is phase distorted.

Actual Variations in R.M.S., Average and Peak Reading. In Fig. A.1b measurements carried out on a Frequency Analyzer Type 2107 are illustrated. Fig. A.1a shows the phase distortion versus frequency. At the high frequencies the phase distortion is to a certain degree dependent on the setting of the attenuators "Meter Range" and "Range Multiplier", therefore two curves are shown giving the highest variation in phase response for possible combinations of the two attenuator positions. In part b of Fig. A.1 is illustrated the variation in meter reading versus frequency and relative to a pure sine wave when the Frequency Analyzer treats a symmetric square-wave signal. The r.m.s. reading shows an increase at the highest frequencies which is due to an increase in the Analyzer's amplitude vs. frequency characteristic beyond the high frequency limit (40 kc/s).

Shape Distortion of Signal with Harmonics. In Fig. A.2 is shown the influence of phase distortion of a symmetrical square-wave signal when treated in the Frequency Analyzer (switched to "2—40000 c/s Linear") and measured on the output "Recorder". Fig. A.2a gives a 2 c/s signal corresponding to the low frequency limit. Fig. A.2b illustrates a 50 c/s signal which will be equal to the shape of the calibration voltage (Ref.) of the apparatus when it is powered from a line voltage with a frequency of 50—60 c/s. As Fig. A.2c shows, no phase distortion is present from the square-wave signal when its fundamental frequency is around 1000 c/s. At the highest frequency, however, phase distortion is again perceptible, which can be seen on Fig. A2d, where the distortion on a 40 kc/s signal is reproduced.

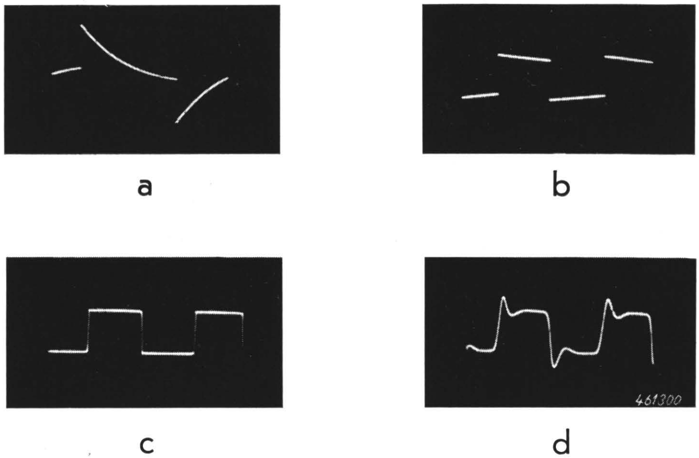


Fig. A.2. Typical shape distortion of a symmetrical square-wave treated in the Frequency Analyzer.
a 2 c/s.
b 50 c/s.
c 1 kc/s.
d 40 kc/s

Specification

Frequency Response: Linear: 2—40000 c/s to within ± 0.5 db (± 0.3 db in the range 5—20000 c/s).

Weighted: According to Curve A, B, and C as proposed in the IEC standard for Precision Sound Level Meters (Helsinki 1961) when Analyzer is equipped with one of B & K Condenser Microphones Type 4131 or 4133.

Selective: Can be used both as frequency analyzer and as distortion factor meter. Frequency scale continuously tunable from 20 to 20000 c/s, through six ranges. Automatic tuning from external motor possible such as the motor in a B & K Level Recorder.
Band pass characteristics of the constant percentage bandwidth type with adjustable selectivity: 20—25—30—35—40 db and max. (approx. 46 db) attenuation 1 octave from the tuned-in frequency. Accuracy of filter top at 40 db octave selectivity is ± 0.5 db with respect to "Linear" ranges. The frequency to which the instrument is tuned is marked on a large, illuminated frequency dial. Frequency accuracy better than ± 1 %. When used as distortion factor meter, the attenuation of the fundamental frequency is more than 60 db. Attenuation 1 octave away from fundamental < 0.5 db.

Sensitivity: Full scale deflection from 100 μV to 1000 V in 10 db steps on two attenuators. Maximum amplification 100 db.

Harmonic Distortion: Input Amplifier, less than 0.1 %.

Noise and Hum Level: When switched as wide band amplifier, the noise level is approx. 15 μV with open input and 5 μV with short circuited input.
When switched as narrow band analyzer: The hum level is approx. 3 μV.
All figures are referred to the input and maximum gain.

Input:
1. "Direct". Input impedance 2.22 MΩ paralleled by 30 μμF.
2. "Input Potentiometer". Input resistance approx. 1 MΩ, the parallel capacity depends on setting. To be used for relative measurements.
3. "Condenser Microphone". 7-poled socket for the B & K Condenser Microphones, Artificial Ears, and Preamplifiers.

Output: "Recorder". Output impedance smaller than 50 Ω in series with 24 μF. Output voltage corresponding to full scale meter deflection approx. 10 V. Maximum available output voltage approx. 45 V peak.

External Filters: "Ext. Filter Input": Impedance approx. 12 Ω. "Ext. Filter Output": Impedance approx. 1.5 MΩ.

Meter: Conveniently illuminated and mirrored instrument scale. Perfectly safeguarded against overload. Accuracy: Approx. 2 % of full scale deflection. Scales 0—10 and 0—31 V (linear), 0—20 db (logarithmic) as well as 3 scales calibrated in % absorption for use in connection with the Standing Wave Apparatus Type 4002.
Switch selection of two meter damping characteristics "Fast" and "Slow" which are in accordance with the proposed IEC standard for Precision Sound Level Meters (Helsinki 1961).

Meter Rectifier: R.M.S., peak (half the peak to peak) or arithmetic average type rectification can be selected by means of a switch. The R.M.S. meter indication is accurate to within 0.5 db for any signal wave form with crest factor smaller than 5.

Polarization Voltage: The polarization voltage for the Condenser Microphone Cartridges can be adjusted between 150 and 250 volts.

Tubes: ECC83 (12AX7) — 6 × ECC81 (12AT7) — EF94 (6AU6) — EFC82 (6U8) — EZ90 (6X4) — OA2 — OB2.

Power Supply: 100—115—127—150—220—240 volts AC. 50—400 c/s. Power consumption is approx. 65 watts.

Cabinet: Mahogany cabinet with handles and lid.

Dimensions: 50 (height) × 40 (width) × 20 (depth excl. dials and knobs) centimetres. 20 (height) × 16 (width) × 8 (depth excl. dials and knobs) inches.

Weight: 20 kg (45 lbs.).

Accessories Included: 1 power cord, 4 screened plugs JP 0018, 1 Flexible Shaft UB 0040. Various fuses and lamps.

B K

Printed in Copenhagen, Denmark

August 1962